Journal of Immigrant and Minority Health (2020) 22:223–231
https://doi.org/10.1007/s10903-019-00888-4

ORIGINAL PAPER

Vaccine-Preventable Disease-Associated Hospitalisations Among Migrant and Non-migrant Children in New Zealand

Nadia A. Charania[1] · Janine Paynter[2] · Arier C. Lee[3] · Donna G. Watson[2] · Nikki M. Turner[2]

Published online: 3 April 2019

Abstract

Migrants may experience a higher burden of vaccine-preventable disease (VPD)-associated hospitalisations compared to the host population. A retrospective cohort study from 2006 to 2015 was conducted that linked de-identified data from government sources using Statistic NZ's Integrated Data Infrastructure. VPD-related hospitalisations were compared between three cohorts of children from birth to 5 years old: foreign-born children who migrated to NZ, children born in NZ of recent migrant mothers, and a comparator group of children born in NZ without a recent migration background. VPD-related hospitalisation rates were higher among NZ-born non-migrant children compared to NZ-born migrant and foreign-born children for all of the diseases of interest. For instance, 5.21% of NZ-born non-migrant children were hospitalised at least once due to all-cause gastroenteritis compared to 4.47% of NZ-born migrant children and only 1.13% of foreign-born migrant children. The overall hospitalisation rate for NZ-born non-migrant children was 3495 hospitalisations per 100,000 person years. Among children with migrant backgrounds, higher hospitalisation rates were noted among those of Pacific ethnicity and those with refugee backgrounds. Those arriving on Pacific visa schemes were hospitalised at rates ranging from 2644/100,000 person years among foreign-born migrant children and 4839/100,000 person years among NZ-born migrant children. Foreign-born quota refugee children and NZ-born children of quota refugee mothers were hospitalised at a rate of 4000–5000/100,000 person years. It is important to disaggregate migrant data to improve our understanding of migrant health. Children need to be age-appropriately vaccinated, and other individual and environmental factors addressed, to reduce the risk of infectious diseases.

Keywords Vaccine-preventable disease · Children · Data-linking · Migrant · Refugee

Background

Economic, social, political and environmental factors have resulted in increased international migration [1–3]. Migration is a complex phenomenon and comprises of a variety of reasons that underpin people's decision to move depending on their ability to choose [4]. People may voluntary relocate for work or study opportunities, and to secure a better future for themselves and their families [4]. In 2017, it was estimated that 258 million people worldwide were international migrants and living outside their country of birth [5]. Moreover, many people are forcibly displaced outside their native country due to fear of persecution; as of 2017, there were 25.4 million refugees, over half of whom were children, and 3.1 million asylum seekers [6]. New Zealand (NZ) accepts migrants, refugees and asylum seekers under various categories and schemes [7] and migrants now represent almost a quarter of NZ's total population [8, 9].

Electronic supplementary material The online version of this article (https://doi.org/10.1007/s10903-019-00888-4) contains supplementary material, which is available to authorized users.

✉ Nadia A. Charania
nadia.charania@aut.ac.nz

[1] Department of Public Health, Auckland University of Technology, 640 Great South Road, Manukau, Auckland 2025, New Zealand

[2] Department of General Practice and Primary Health Care, University of Auckland, 261 Morrin Road, St. Johns, Auckland 1072, New Zealand

[3] Section of Epidemiology and Biostatistics, University of Auckland, 261 Morrin Road, St. Johns, Auckland 1072, New Zealand

With steadily increasing numbers of migrants and refugees worldwide, there is an increased possibility of infectious disease outbreaks occurring due to the transmission of vaccine-preventable diseases (VPDs), such as polio and measles, across national borders [10]. Previous studies indicate that migrants and refugees experience higher rates of VPD-associated hospitalisation, morbidity and mortality compared to the host population [11, 12]. A recent Canadian study reported that immigrants had higher age-standardised hospitalisation rates for VPDs compared to the non-migrant population; these rates increased with years spent in Canada and were highest amongst Southeast and East Asian immigrants [11]. The disproportionate burden of VPD-related hospitalisations among migrants and refugees may be attributable to under-immunisation due to challenges with accessing vaccines either in their country of origin, in transit and/or post-arrival in their host country [12–14]. Migrants and refugees have special health needs that require comprehensive care post-arrival [15–17], yet they may experience difficulties accessing health care services, including vaccinations, due to language, cultural and economic barriers [18]. Moreover, newly arrived migrants and refugees may experience factors, such as poor housing, overcrowding and malnutrition, that can also make them more vulnerable to infectious diseases [12, 19, 20].

To guide optimal migrant-related policy and practice, it is important to understand the VPD burden experienced by migrants and refugees compared to the host population. The aim of this study was to examine the burden of VPD-related hospitalisations among migrant and non-migrant children living in NZ by linking health datasets with immigration information.

Methods

Participants

This study presents part of a larger retrospective cohort study that examined immunisation coverage and VPD-related hospitalisations across three NZ cohorts of children from birth to 5 years old, from 1 January 2006 to 31 December 2015. Data related to immunisation coverage have been published elsewhere [21] and data related to VPD-related hospitalisations are presented herein. Foreign-born migrant children (Cohort A) were born overseas and migrated to NZ during the study period. NZ-born migrant children (Cohort B) were born in NZ of women who migrated to NZ during the study period (hereafter recent migrants). Non-migrant children (Cohort C, the comparator group) were born in NZ without a recent history of migration. Only migrant children who stayed in NZ longer than 3 months were included. Children were excluded if data inconsistencies (e.g., a birth date occurring after a travel date) were present.

Data Collection and Measures

De-identified health and immigration data were retrieved from various government administrative sources for the following variables, including the Ministry of Health's National Health Index (NHI) dataset for demographic data [e.g., month and year of birth, month and year of death, sex, prioritised ethnicity (see below for explanation), nationality (i.e., country that issued their passport)] and the National Minimum Data Set (NMDS) for hospitalisation data (e.g., hospitalisation event for selected diseases); Ministry of Business, Innovation and Employment and NZ Customs Journey datasets for immigration and travel data (e.g., visa type, time spent in NZ); and the Department of Internal Affairs for birth data. For individuals with multiple nationalities, the non-NZ nationality was reported if NZ was one of the nationalities or the earliest recorded nationality was reported if NZ was not one of the nationalities. Ethnicity was reported based on that recorded in the NHI dataset (as it provides more detail) and grouped according to Statistics NZ's Levels 1 and 2 ethnicity classifications; Statistics NZ is the country's official data agency that collects statistical information about people and organisations through censuses and surveys [22].

The primary outcome measure was hospitalisation event, obtained from the MOH's NMDS. The NMDS routinely tracks hospitalisation discharge information provided by public and private hospitals, along with coded clinical data for inpatients and day patients [23]. The classification system used to identify different diseases was the ICD-10-AM, the International Statistical Classification of Diseases and Related Health Problems, Tenth Revision, Australian Modification. This consists of a tabular list of diseases and accompanying index. Specific codes associated with each VPD outcome of interest are shown in Supplementary file 1. Relevant data fields of interest included: NHI number, admission event ID, admission date and diagnosis code. VPD-associated hospitalisation rates for gastroenteritis (all-cause); rotavirus gastroenteritis; pneumonia (all-cause); measles, mumps, rubella (MMR); otitis media (OM); invasive pneumococcal disease (IPD); *Haemophilus influenzae* type b (Hib); and whooping cough (pertussis) were selected for this study. The diseases selected may be prevented by vaccines; however, hospitalisations can also be caused by organisms not targeted by vaccines included on the National Immunisation Schedule (NIS) (https://www.health.govt.nz/our-work/preventative-health-wellness/immunisation/new-zealand-immunisation-schedule).

Demographic information (e.g., month and year of birth, month and year of death, sex, prioritised ethnicity,

and most recent residential location) is associated with each individuals' National Health Index (NHI) number, a unique alphanumeric identifier assigned at birth or first contact with health care services. Statistics NZ's Integrative Data Infrastructure (IDI) was used to link data with NHIs using the encrypted NHI index. Data without a standard identifier were linked using probabilistic linking originally by Statistics NZ, who assigned an encrypted identifier that we then used in this study to link the data. The version of the IDI used was the September 2016 refresh.

Analysis

Selection of relevant data, data linkage and recoding of variables were done using SAS Enterprise Guide 7.1. Each cohort is described and compared using counts and percentages summarising each variable of interest, including ethnicity, nationality, visa category and hospitalisation event. Rates of hospitalisation are expressed as rate per 100,000 person years. Poisson regression modelling, with adjustment for clustering and overdispersion, was used to compare hospitalisation rates for each cohort and adjust for age, ethnicity and gender. Regression model outputs are expressed as incidence rate ratios.

Ethical approval to conduct this study was granted by the University of Auckland Human Participants Ethics Committee (UAHPEC, reference number: 017200).

Results

Description of Cohorts

Figure 1 shows the number of children included in each cohort after applying exclusions.

The demographic characteristics of children in all three cohorts are presented in Table 1. Among foreign-born migrant children (Cohort A; N = 75,375), the largest ethnic group was European (30.5%) followed by Asian (19.2%). Many migrants do not require visas to enter NZ due to their Country of Origin or they are returning expatriates. Of those with visa data (54.2%), the combined categories of work, visitor and student visas were the most common (37.0%) while small numbers arrived on refugee-related visas.

Among NZ-born migrant children (Cohort B; N = 50,136), while just above a quarter identified as European (28.3%), the combined Asian ethnic group was the largest (48.9%). Of those with visa data (92.1%), most children were born to migrant mothers who first came to NZ on work, visitor or student visas (44.6%).

More than half of the NZ-born non-migrant children (Cohort C; N = 567,408) identified as European (54.1%); other large ethnic groups were Māori, the indigenous people of NZ, (25.0%) and Pacific (10.6%).

VPD-Associated Hospitalisation Rates

Within each cohort for individual selected diseases, < 5% of children were hospitalised at least once, except for all-cause gastroenteritis for Cohort C (Table 2). The

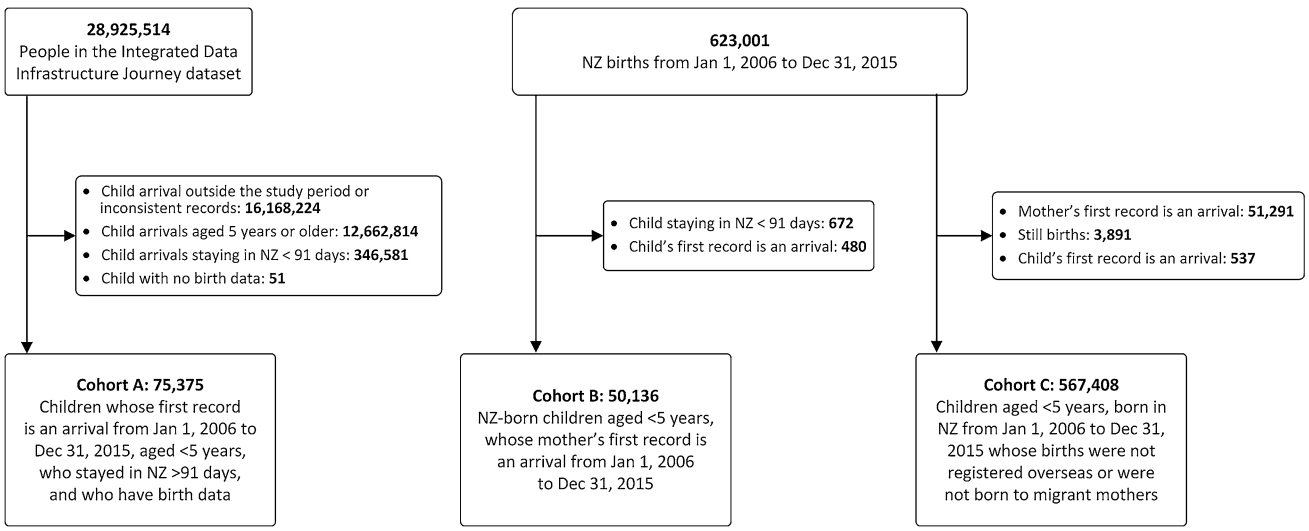

Fig. 1 Participant flow chart of eligible children for Cohorts A, B and C and exclusions (some children were counted in multiple exclusion categories). It is a policy of Statistics NZ that counts are randomly rounded to a number divisible by three in order to protect privacy; thus, the numbers of inclusions and exclusions will not reconcile precisely

Table 1 Demographic characteristics of children in Cohorts A, B and C

	Cohort A		Cohort B		Cohort C	
	N = 75,375		N = 50,136		N = 567,408	
	n	(%)	n	(%)	n	(%)
Ethnicity						
European	23,007	(30.5)	14,202	(28.3)	306,960	(54.1)
NZ Māori	3741	(5.0)	966	(1.9)	141,840	(25.0)
Pacific Island	7023	(9.4)	6450	(12.9)	59,922	(10.6)
Asian	14,418	(19.2)	24,543	(48.9)	48,021	(8.4)
MELAA[a]	2418	(3.2)	3498	(7.0)	6759	(1.1)
Other	192	(0.3)	141	(0.3)	306	(0.1)
Missing	24,573	(32.6)	333	(0.7)	3594	(0.6)
Visa category	Based on child's visa		Based on mother's visa		Visa data not applicable	
Refugee (quota)	330	(0.4)	216	(0.4)	–	–
Pacific	1680	(2.2)	945	(1.9)	–	–
International (non-Pacific)/Refugee (non-quota)	519	(0.6)	675	(1.3)	–	–
Convention refugee	384	(0.5)	501	(1.0)	–	–
Refugee family	99	(0.1)	108	(0.2)	–	–
Humanitarian	36	(< 0.1)	66	(0.1)	–	–
Residence	5169	(6.9)	5052	(10.1)	–	–
Family	1791	(2.4)	5136	(10.2)	–	–
Adopted child	156	(0.2)	–	–	–	–
Child of citizen or resident	1650	(2.2)	45	(0.1)	–	–
Work	–	–	16356	(32.6)	–	–
Work and student	2,523	(3.3)	219	(0.4)	–	–
Work and visitor	16,818	(22.3)	648	(1.3)	–	–
Visitor	8,559	(11.4)	4773	(9.5)	–	–
Overstay	450	(0.6)	897	(1.8)	–	–
Medical treatment	87	(0.1)	9	(< 0.1)	–	–
Working holiday	–	–	1143	(2.3)	–	–
Student parent	–	–	351	(0.7)	–	–
Seasonal work	–	–	69	(0.1)	–	–
Other	1053	(1.4)	9645	(19.2)	–	–
Visa not required or missing[b]	34,548	(45.8)	3951	(7.9)	–	–

Cohort A are foreign born migrant children; Cohort B are New Zealand born children of recent migrant mothers; Cohort C are New Zealand born children without a recent migration background

[a]Middle Eastern, Latin American or African

[b]The majority of this group included migrants from countries where a visa for New Zealand is not needed (e.g., Australia) and returning expatriates

proportion of children who had repeat hospitalisations was low as well with < 1% of children being admitted twice or more. For all of the selected diseases, NZ-born non-migrant children (Cohort C) had higher rates of hospitalisations and repeat hospitalisations compared to children with migrant backgrounds (Cohorts A and B) (Table 2). For instance, 5.21% of NZ-born non-migrant children were hospitalised at least once due to all-cause gastroenteritis compared to only 1.13% of foreign-born migrant children and 4.47% of NZ-born migrant children.

Across all three cohorts by disease, the majority of disease contribution was from all-cause gastroenteritis (35.4, 48.9 and 37.4% for Cohorts A, B and C respectively), all-cause pneumonia (24.9, 23.6 and 22.5% for Cohorts A, B and C respectively) and OM (37.8, 24.3 and 35.8% for Cohorts A, B and C respectively). MMR, IPD, Hib and pertussis all

Table 2 Number of children with at least one hospitalisation for selected diseases with some vaccine-preventable element for each cohort from January 1, 2006 to December 31, 2015, New Zealand

	Cohort A		Cohort B		Cohort C	
Total number in cohort (denominators)	N = 75,375		N = 50,136		N = 567,408	
Disease	n	(%)	n	(%)	n	(%)
Gastroenteritis (all-cause)	855	(1.13)	2241	(4.47)	29,565	(5.21)
Rotavirus gastroenteritis[a]	330	(0.44)	975	(1.94)	13,980	(2.46)
Pneumonia (all-cause)	603	(0.80)	1080	(2.15)	17,793	(3.14)
Measles, mumps, rubella[b]	9	(0.01)	6	(0.01)	111	(0.02)
Otitis media	915	(1.21)	1113	(2.22)	28,290	(4.99)
Invasive pneumococcal disease	18	(0.02)	15	(0.03)	411	(0.07)
Haemophilus influenzae Type B (Hib)	24	(0.03)	81	(0.16)	1848	(0.33)
Whooping cough (Pertussis)	6	(0.01)	48	(0.09)	945	(0.17)

Proportions calculated with total numbers of children in cohorts as denominators. The median ages with interquartile ranges of the children at the close of the study period were Cohort A 7.3 (4.8–9.7), Cohort B 2.9 (1.3–5.0), Cohort C 5.3 (2.8–7.7)

[a]Rotavirus hospitalisations do not contribute to the total N as rotavirus hospitalisations were a subset of gastroenteritis hospitalisations

[b]These hospitalisations combine measles, mumps and rubella. It also includes 2011 data when there was a measles epidemic in New Zealand. Further information on measles, mumps and rubella epidemiology including recent rates is available from: https://surv.esr.cri.nz/PDF_surveillance/NZPHSR/2016/NZPHSRMay2016.pdf

contributed about 2–4% of the combined disease burden in all cohorts. The contribution to hospitalisation from diseases varied between the cohorts. All-cause gastroenteritis was the cause of hospitalisations for just under half of Cohort B (48.9%), but only over a third of Cohorts A and C (35.4% and 37.4% respectively). Also, just over a third of Cohorts A and C (37.8% and 35.8% respectively) were hospitalised due to OM compared to only 24.3% of Cohort B.

Children from Cohorts A and B were significantly less likely [incidence rate ratio (IRR) 0.80, 95% confidence interval (CI) 0.77–0.84; IRR 0.96, CI 0.93–0.99, respectively] to be hospitalised compared to children in Cohort C after adjusting for gender, ethnicity and age group (Table 3). Pacific children had the highest incidence of hospitalisation while Asian children were significantly less likely to be hospitalised compared to European and Other ethnicities. Male children were more likely to be hospitalised compared to female children. Regarding age at hospitalisation, younger children (under 2 years old) were 2–3 times more likely to be hospitalised than older children (4 years old).

The overall hospitalisation rate for children without a migrant background (Cohort C) was 3495 hospitalisations per 100,000 person years. Among children with migrant backgrounds (Cohorts A and B), those with refugee backgrounds had the highest hospitalisation rates (Table 4). For instance, quota refugee children in Cohorts A and B were hospitalised at a rate of 4000–5000/100,000 person years. Moreover, across both cohorts, children or children of mothers who arrived on Pacific visa schemes, including the Pacific Access and Samoan Quota categories, were also hospitalised at particularly high rates ranging from 2644/100,000 person years in Cohort A to 4839/100,000 person years in Cohort B. Foreign-born migrant children (Cohort A) of parents on work and student visas and visitor visas had the lowest rates of hospitalisation with rates of 978/100,000 person years and 1136/100,000 person years,

Table 3 Poisson regression results presented as incidence rate ratios comparing incidence of hospitalisations of the three different cohorts adjusting for gender, ethnicity and age group

	IRR	95% CI		P
Cohort				
A	0.80	0.77	0.84	<.0001
B	0.96	0.93	0.99	0.0074
C	Ref			
Gender				
Female	0.82	0.81	0.83	<.0001
Male	Ref			
Ethnicity				
Asian	0.83	0.81	0.86	<.0001
MELAA	1.06	1.02	1.11	0.0083
Māori	1.38	1.36	1.41	<.0001
Pacific peoples	1.75	1.71	1.78	<.0001
European and other	Ref			
Age group				
0 to < 1	2.80	2.71	2.88	<.0001
1 to < 2	3.09	3.00	3.19	<.0001
2 to < 3	1.75	1.69	1.81	<.0001
3 to < 4	1.15	1.11	1.20	<.0001
4 to < 5	Ref			

Table 4 Hospitalisations for selected diseases with some vaccine-preventable element for Cohort A and B by visa group from January 1, 2006 to December 31, 2015, New Zealand

	Cohort A (child's visa)			Cohort B (mother's visa)		
Total number in cohort	N = 75,375			N = 50,136		
Visa group	Hospitalisations	Person-years	Rate per 100,000 person-years	Hospitalisations	Person-years	Rate per 100,000 person-years
Refugee (quota)	21	537	3911	24	489	4908
International (non-Pacific)/refugee (non-quota)	39	1239	3148	108	2286	4724
Convention refugee and humanitarian[a]	33	1044	3161	–	–	–
Humanitarian	–	–	–	9	228	3947
Convention refugee	–	–	–	84	1746	4811
Refugee family	6	195	3077	15	312	4808
Pacific	81	3063	2644	135	2790	4839
Residence	162	8892	1822	384	14,634	2624
Family	66	3336	1978	372	14,553	2556
Adopted child[b]	S	S	S	–	–	–
Child of citizen or resident	66	3636	1815	6	147	4082
Work[c]	–	–	–	1218	44,817	2718
Work and student	21	2148	978	18	459	3922
Work and visitor	369	29,712	1242	45	1893	2377
Working holiday[c]	–	–	–	75	2445	3067
Seasonal work[c]	–	–	–	6	180	3333
Student parent[c]	–	–	–	18	759	2372
Visitor	129	11,352	1136	417	13,362	3121
Overstay	15	942	1592	93	2784	3341
Other	24	1674	1434	735	27,537	2669
Medical treatment	S	S	S	S	S	S
Visa not required or missing[d]	1185	60,696	1952	390	11,328	3443

[a]Aggregated because of low numbers for Cohort A

[b] Visa category not applicable for Cohort B

[c]Visa category not applicable for Cohort A

[d]The majority of this group included migrants from countries where a visa for New Zealand is not needed (e.g., Australia) and returning expatriates

respectively. For NZ-born migrant children (Cohort B), the lowest hospitalisation rates were noted among children with parents on student parent visas (2372/100,000 person years) and work and visitor visas (2377/100,000 person years).

Discussion

To the authors' knowledge, this is the first national study to explore differences in VPD burden among children in relation to their migration background. Based on linked, de-identified government data, our study revealed that children of migrant backgrounds were less likely to be hospitalized compared to NZ-born non-migrant children after controlling for gender, ethnicity and age. Previous studies have examined the effects of migration background on VPD-related burden in other high-income countries and found contrasting results to ours. For instance, a German study found that children with a migration background were at a higher risk for hepatitis B infection compared to non-migrants [24]. A Canadian study found higher VPD-associated hospitalisation rates among migrants compared to non-migrants [11]. Moreover, a Danish study reported higher mortality risks among migrants and refugees compared to the host population [25].

The lower VPD-associated hospitalisation rates noted among children of migrant backgrounds compared to the host population aligns with the concept of the 'healthy migrant effect' (HME). The HME states that migrants initially can be healthier with lower overall morbidity and

mortality than the host population due to self-selection, cultural buffering and social networks, and immigration health screening processes [26, 27]. This phenomenon has been thought to be short-lived as the health profiles of migrants tend to conform to those of the host population likely due to environmental and behavioural factors (e.g., substandard living and employment conditions, etc.) [27–29]. In our study, children of migrant mothers have a burden of disease in between migrant children and children without a migrant background which supports the HME and reflects the transition as environmental and behavioural factors of their new home increase in influence over time. The HME is not likely to apply to all migrants as it overlooks heterogeneity among migrants in relation to their country of birth, reasons for migrating and duration of residence in the host country [30–32]. In our study, we found that children with refugee backgrounds and of Pacific ethnicities had particularly high hospitalisation rates thereby highlighting the importance of disaggregating migrant data.

Among children with migrant backgrounds, VPD-related hospitalisation rates varied depending on the visa held upon entry, with those on refugee visa schemes experiencing a disproportionate burden. Previous Canadian research also noted higher hospitalisation rates among refugees compared to those in other immigrant categories [11, 32]. The differential disease burden seen by visa type may reflect different health status due to varying economic, social, political and environmental circumstances in migrants' countries of origin and surrounding their reason to migrate. For instance, refugees are forced to migrate and experience a range of traumatic events and stress resulting in complex health needs [17, 33]. It may also reflect different awareness, access and utilisation of health services among migrants in their country of origin, while in transit or in NZ post-arrival. For instance, it has been noted that refugees experience considerable barriers with accessing and utilising health services post-arrival [13, 18, 34]. Moreover, in NZ, the type of visa and length of stay granted determines whether or not health care is publicly funded [35, 36]. Those on work, student and visitor visas for a length of stay <2 years may have to privately pay for health care, which may negatively influence their utilisation of hospital services and thus result in lower VPD-related hospitalisation rates compared to those on longer-term and permanent resident visas who are entitled to publicly funded services.

Incidence of VPD-associated hospitalisations varied by ethnicity in our study. Across the cohorts, those of Asian ethnicities were significantly less likely to be hospitalised while those of Middle Eastern, Latin American or African (MELAA), Māori and Pacific ethnicities were significantly more likely to be hospitalised compared to those of European and Other ethnicities. This finding may be attributable to pro-immunisation beliefs and perceived ease of accessing immunisations among Asians [37]. Although, some NZ studies have reported no ethnic-related differences in hospitalisations among children for rotavirus [38] and acute OM [39], others revealed that hospitalisations rates were higher among Pacific Island and Māori children compared to European children due to rotavirus [40] and pneumonia [41, 42].

To reduce VPD-related hospitalisation rates, it is important that children are age-appropriately vaccinated. In NZ, all children, regardless of their immigration or citizenship status, are eligible to receive vaccinations as per the NIS [43]. We have previously found that foreign-born migrant children had lower recorded rates by vaccine, ethnicity and visa category compared to NZ-born migrant and non-migrant children [21]. Moreover, migrant children from many Pacific Island ethnicities had lower reported immunisation coverage compared to other ethnicities and higher rates of not age-appropriately vaccinated were noted among foreign-born children on refugee, Pacific and humanitarian visa schemes [21]. These findings were likely influenced by shortfalls around recording immunisation data, particularly vaccinations given to foreign-born children in their country of origin, but potential challenges around engagement with immunisation services for migrant children were also likely to be an issue [21]. Previous research indicated that migrants and refugees experience access and uptake barriers at the health care provision level due to language, transportation, and economic difficulties, along with poor health literacy and limited understanding of how to navigate the country's health system [44–47]. Moreover, previous negative health care experiences and fear of being judged or discriminated by friends, family and health care professionals may negatively impact healthcare utilisation among migrants and refugees [44, 45].

Study Strengths and Limitations

The strengths of this study are the use of a national child population over a 10-year period and the ability to link government datasets to quantify VPD-related hospitalisations in relation to children's migration background. Studies using existing administrative data for purposes other than those for which the data were originally collected require that some assumptions be made. Because the population size for some subgroups were small, there may be variation and limited statistical power for some groups of interest. Moreover, some inaccuracies may have been introduced into the analyses as we were not able to control which variables were available or the value categories within them. Definitions of the diseases of interest were broad and will include hospitalisations due to infectious diseases not targeted by vaccines, which will be the case particularly for gastroenteritis. Further, our results may present an underestimation of the

actual VPD-related cases among children in NZ as we only captured hospitalisation events.

Certain study variables were chosen to maintain the focus of this study. Further analyses would be possible due to NZ's data collection capabilities that support robust data linking across various databases for a national sample of children. Future research could examine the impact of transitioning through different visa categories, patterns of travel, and duration of residence on rates of VPD-related hospitalisations among migrant children. Moreover, future research should explore associations between VPD-related hospitalisations and host and environmental risk factors beyond vaccination among migrant and non-migrant children. Given that our study likely represents an underestimation of VPD cases, future research should also explore health-seeking behaviour and rates of accessing primary care to better understand the burden of VPDs among migrant and non-migrant children.

Conclusion

The use of linked government national databases allows for the examination of VPD-related hospitalisation events by migrant background. Contrary to previous studies, evidence from this study revealed that overall NZ-born non-migrant children experienced higher VPD-related hospitalisations compared to NZ-born migrant and foreign-born children. However, certain subgroups experienced higher rates of disease, including those of Pacific ethnicities and those entering on refugee visas. Migrants and refugees are not a homogeneous group, and as such, it is important to identify higher risk groups and support targeted efforts to provide these particularly vulnerable groups with accessable, affordable, and culturally- and linguistically-appropriate health care services. With increasing immigration and changing demography of migrants and refugees, this data-linking study reveals valuable information to guide policy and practice to reduce the impact and socioeconomic burden of VPD-related outbreaks.

Summary Statistics New Zealand Security Statement

The presented Red Knot (Huahou) Study is a study of the immunisation coverage among migrant and refugee children in New Zealand, based on the integration of anonymised population census data from Statistics New Zealand and mortality data from the New Zealand Health Information Service. This project was approved by Statistics New Zealand as a Data Laboratory project under the Microdata Access Protocols in 1997. The datasets created by the integration process are covered by the Statistics Act 1975 and can be used for statistical purposes only. Only approved researchers who have signed Statistics New Zealand's declaration of secrecy can access the integrated data in the Data Laboratory. For further information about confidentiality matters in regard to this study please contact Statistics New Zealand.

Acknowledgements This study was conducted in collaboration with Statistics New Zealand and within the confines of the Statistics Act 1975. We would like to thank members of The Monarch Collaboration (http://monarchcollaboration.org/) for their support of this study. This work was supported by the Ministry of Business, Innovation and Employment (MBIE) (Grant Number #:UOAX1512). MBIE was provided the opportunity to review a preliminary version of this manuscript for factual accuracy but the authors are solely responsible for final content and interpretation. The authors received no financial support or other form of compensation related to the development of the manuscript.

Compliance with Ethical Standards

Conflict of interest Janine Paynter, Arier C. Lee, Donna G. Watson have helped conduct and Nikki M. Turner has been an investigator in research projects funded by GlaxoSmithKline. Nadia A. Charania reports no conflict of interest.

References

1. Castles S. International migration at the beginning of the twenty-first century: global trends and issues. ISSJ. 2000;165:269–81.
2. Abel GJ, Sander N. Quantifying global international migration flows. Science. 2014;343(6178):1520–2.
3. Beine M, Parsons C. Climatic factors as determinants of international migration. Scand J Econ. 2015;117(2):723–67.
4. International Organization for Migration (IOM). World Migration Report 2018. Geneva: International Organization for Migration. 2017. https://publications.iom.int/system/files/pdf/wmr_2018_en.pdf. Accessed 5 July 2018.
5. United Nations, Department of Economic and Social Affairs, Population Division. International Migration Report 2017: highlights. New York: United Nations. 2017. http://www.un.org/en/development/desa/population/migration/publications/migrationreport/docs/MigrationReport2017_Highlights.pdf. Accessed 23 Jan 2018.
6. United Nations High Commissioner for Refugees (UNHCR). Global trends: forced displacement in 2017. Geneva: United Nations High Commissioner for Refugees. 2018. http://www.unhcr.org/5b27be547.pdf. Accessed 21 Aug 2018.
7. Immigration New Zealand. New Zealand Refugee Quota Programme. Wellington: Immigration New Zealand. 2018. https://www.immigration.govt.nz/about-us/what-we-do/our-strategies-and-projects/supporting-refugees-and-asylum-seekers/refugee-and-protection-unit/new-zealand-refugee-quota-programme. Accessed 25 March 2018.
8. Merwood P. Labour market outcomes of recent migrants to New Zealand. Wellington: Ministry of Business, Innovation and Employment. 2013. https://www.mbie.govt.nz/publications-research/research/migrants—settlement/recent-migrants-nz.pdf. Accessed 25 Jan 2017.
9. Statistics New Zealand. International Travel and Migration: October 2017. Wellington: Statistics New Zealand. 2017. http://archive.stats.govt.nz/browse_for_stats/population/Migration/IntTravelAndMigration_HOTPOct17.aspx. Accessed 25 March 2018.

10. Gushulak BD, MacPherson DW. Globalization of infectious diseases: the impact of migration. CID. 2004;38(12):1742–8.
11. Ng E, et al. Vaccine-preventable disease-related hospitalization among immigrants and refugees to Canada: study of linked population-based databases. Vaccine. 2016;34(37):4437–42.
12. Lam E, et al. Displaced populations due to humanitarian emergencies and its impact on global eradication and elimination of vaccine-preventable diseases. Confl Health. 2015;10(1):27.
13. Morris MD, et al. Healthcare barriers of refugees post-resettlement. J Commun Health. 2009;34(6):529–38.
14. Paxton GA, et al. East African immigrant children in Australia have poor immunisation coverage. JPCH. 2011;47(12):888–92.
15. Hobbs M, et al. The health status of asylum seekers screened by Auckland Public Health in 1999 and 2000. NZMJ. 2002;115(1160):u152.
16. McLeod A, Reeve M. The health status of quota refugees screened by New Zealand's Auckland Public Health Service between 1995 and 2000. NZMJ. 2005;118(1224):u1702.
17. Rungan S, et al. Health needs of refugee children younger than 5 years arriving in New Zealand. Pediatr Infect Dis. 2013;32(12):e432–6.
18. Lawrence J, Kearns R. Exploring the 'fit' between people and providers: refugee health needs and health care services in Mt Roskill, Auckland, New Zealand. Health Soc Care Commun. 2005;13(5):451–61.
19. Semenza JC, et al. Public health needs of migrants, refugees and asylum seekers in Europe, 2015: infectious disease aspects. Eur J Public Health. 2016;26(3):372–3.
20. Ziersch A, et al. Exploring the relationship between housing and health for refugees and asylum seekers in South Australia: a qualitative study. Int J Environ Res Public Health. 2017;14(9):1036.
21. Charania NA, et al. Exploring immunisation inequities among migrant and refugee children in New Zealand. Hum Vaccin Immunother. 2018;14:1–8.
22. Statistics New Zealand. Ethnicity. Wellington: Statistics New Zealand. Not dated. http://archive.stats.govt.nz/methods/classifications-and-standards/classification-related-stats-standards/ethnicity.aspx. Accessed 25 March 2017.
23. National Health Board. National Minimum Dataset (Hospital Events) data dictionary. Wellington: Ministry of Health. 2014. https://www.health.govt.nz/publication/national-minimum-dataset-hospital-events-data-dictionary. Accessed 25 March 2017.
24. Cai W, et al. Hepatitis B virus infections among children and adolescents in Germany: migration background as a risk factor in a low seroprevalence population. Pediatr Infect Dis J. 2011;30(1):19–24.
25. Norredam M, et al. Mortality from infectious diseases among refugees and immigrants compared to native Danes: a historical prospective cohort study. Trop Med Int Health. 2012;17(2):223–30.
26. Singh GK, Miller BA. Health life expectancy, and mortality patterns among immigrant populations in the United States. Can J Public Health. 2004;95(3):I14–21.
27. Domnich A, et al. The "healthy immigrant" effect: does it exist in Europe today? IJPH. 2012;9(3):e7532-1-7.
28. Fennelly K. The ''healthy migrant'' effect. Minn Med. 2007;90(3):51–3.
29. Correa-Velez I, et al. Hospital utilisation among people born in refugee-source countries: an analysis of hospital admissions, Victoria, 1998-2004. Med J Aust. 2007;186(11):577–80.
30. Ng E. The healthy immigrant effect and mortality rates. Health Rep. 2011;22(4):2–9.
31. Rotermann M. The impact of considering birthplace in analyses of immigrant health. Health Rep. 2011;22(4):37–43.
32. Ng E, Sanmartin C, Manuel DG. Acute care hospitalization, by immigrant category: linking hospital data and the Immigrant Landing File in Canada. Health Rep. 2016;27(8):12–8.
33. Burnett A, Peel M. Health needs of asylum seekers and refugees. BMJ. 2001;322(7285):544–7.
34. McKeary M, Newbold B. Barriers to care: challenges for Canadian refugees and their health care providers. J Refug Stud. 2010;23(4):523–45.
35. Ministry of Health. Eligibility for publicly funded health services. Wellington: Ministry of Health. 2011. https://www.health.govt.nz/new-zealand-health-system/eligibility-publicly-funded-health-services. Accessed 5 July 2018.
36. New Zealand Government. Paying for healthcare services. Wellington: New Zealand Government. 2018. https://www.newzealandnow.govt.nz/living-in-nz/healthcare/paying-for-healthcare-services. Accessed 5 July 2018.
37. Pal M, Goodyear-Smith F, Exeter D. Factors contributing to high immunisation coverage among New Zealand Asians. J Prim Health Care. 2014;6(4):304–11.
38. Grimwood K, et al. Rotavirus hospitalisation in NZ children under 3 years of age. J Paediatr Child Health. 2006;42(4):196–203.
39. Gribben B, et al. The incidence of acute otitis media in New Zealand children under five years of age in the primary care setting. J Prim Health Care. 2012;4(3):205–12.
40. Ardern-Holmes SL, et al. Trends in hospitalization and mortality from rotavirus disease in New Zealand infants. Pediatr Infect Dis J. 1999;18(7):614–9.
41. Grant CC, et al. Hospitalisation for pneumonia in children in Auckland, New Zealand. J Paediatr Child Health. 1998;34(4):355–9.
42. Petousis-Harris H, et al. Pneumococcal conjugate vaccines turning the tide on inequity—a retrospective cohort study of New Zealand children born 2006-2015. Clin Infect Dis. 2018. https://doi.org/10.1093/cid/ciy570.
43. Ministry of Health. Immunisation handbook 2017. Wellington: Ministry of Health; 2017.
44. Sheikh-Mohammed M, et al. Barriers to access to health care for newly resettled sub-Saharan refugees in Australia. Med J Aust. 2006;185(11–12):594–7.
45. Drummond PD, et al. Barriers to accessing health care services for West African refugee women living in Western Australia. Health Care Women Int. 2011;32(3):206–24.
46. Sheikh M, MacIntyre CR. The impact of intensive health promotion to a targeted refugee population on utilisation of a new refugee paediatric clinic at the children's hospital at Westmead. Ethn Health. 2009;14(4):393–405.
47. Riggs E, et al. Accessing maternal and child health services in Melbourne, Australia: reflections from refugee families and service providers. BMC Health Serv Res. 2012;12:117.